LOW VOLTAGE STANDARDS IN THE 10 HZ TO 1 MHZ RANGE

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Abstract

A step down procedure is described for establishing voltage standards in the 1 mV to 100 mV range at frequencies between 10 Hz and 1 MHz. The step down employs low voltage thermal voltage converters and micropotentiometers. Techniques are given for measuring input impedance and calculating loading errors.

I. Introduction

A commonly used method of generating millivoltages is to convert a known current to a voltage in a micropotentiometer (μpot). These devices were originally developed as low voltage rf sources with relative uncertainties of around 1%. However, it has been shown that μpots can be used to generate 1 mV to 100 mV signals from 10 Hz to 1 MHz with errors ranging from 20 to 200 μV/V [1]. Standards in this voltage and frequency range are required to support low voltage thermal voltage converters (TVCs) and digital voltmeters and multimeters (DMMs).

II. Step down Procedure

Low-voltage ac standards are established at NIST through a step-down procedure involving TVCs and μpots. A characterized 250 mV TVC (a coaxially mounted single junction thermoelement) is used at 100 mV to calibrate a multirange low voltage TVC. It is assumed that the ac-dc difference of the 250 mV TVC is the same at 100 mV as it is at full scale. A 100 mV μpot is calibrated at full scale by the low voltage TVC and then used to calibrate the low voltage TVC at 50 mV. The μpots are based on single junction thermoelements, and it is also assumed that their ac-dc differences do not change when operated at reduced current. This procedure, where each device is calibrated at full scale and used near half scale to calibrate the low voltage TVC, is employed to step down to 1 mV. A more detailed description of the procedure, including the uncertainties associated with each step, will be given in the final paper.

III. Loading errors

The output resistance, R_S, of a 100 mV μpot may be as high as 20 Ω. To obtain the lowest uncertainties, it is necessary to pay close attention to the input impedance of the device used to measure the μpot output voltage. In the low voltage TVC, input signals are amplified before they are measured. The input stage is a wide band operational amplifier configured with a gain of 10 in a noninverting mode. The input impedances are typically quite high at low frequencies. However, as the frequency increases, the amplifier loop gain diminishes and the input resistance decreases. Budovsky and Klonz have shown that the input resistance of the low voltage TVC may fall from 10 MΩ in the audio frequency range to less than 100 kΩ at 1 MHz.

The input resistance, R_I, of the low voltage TVC is easily measured using an impedance (LCR) meter. Assuming that the input reactance has a negligible influence, the loading error, E, is:

$$E = R_I / (R_I + R_S) - 1. \qquad (1)$$

For a 100 mV measurement with a 20 Ω source resistance, R_S, and a 100 kΩ input resistance, R_I, E = -200 μV/V. An uncertainty of 2.5% in the impedance measurement will cause an uncertainty

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of only 5 µV/V in the loading error. This uncertainty is about 10 times smaller than the 2 sigma uncertainty of the ac-dc difference at 100 mV at 1 MHz.

To verify the LCR meter data, a technique was developed in which a small resistance is inserted in series between the µpot and the low voltage TVC and a small capacitance is inserted across the input of the low voltage TVC. Measurements are made in four different configurations and a mathematical model is used to determine the input resistance, R_I, and input capacitance, C, of the TVC. The loading error, E, is described in terms of R_I, C, the output resistance of the µpot, R_S, and the frequency ω:

$$E = \{R_I / [(R_I + R_S)^2 + (\omega C R_I R_S)^2]^{1/2}\} - 1. \qquad (2)$$

The influence of the different measurement methods and input capacitance on the loading error is shown in Fig. 1.

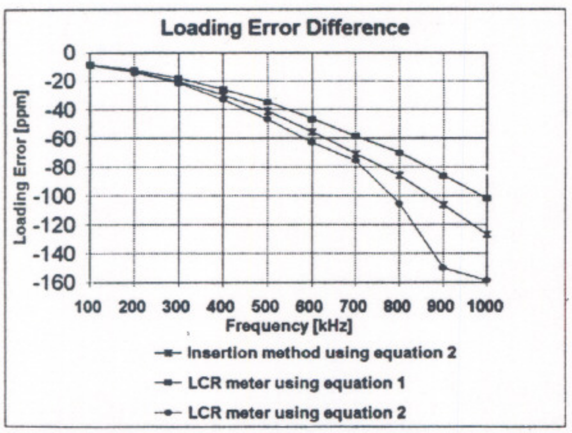

Fig. 1. Difference in loading error vs frequency for $R_S = 20\ \Omega$, and R_I and C measured using either an LCR meter or the insertion method.

The input resistance of a test device, such as a digital multimeter, must also be known to determine how it influences the µpot output voltage. The input resistances vs frequency of two low voltage TVCs of the same type and three high accuracy DMMs from different manufacturers are shown in Fig. 2.

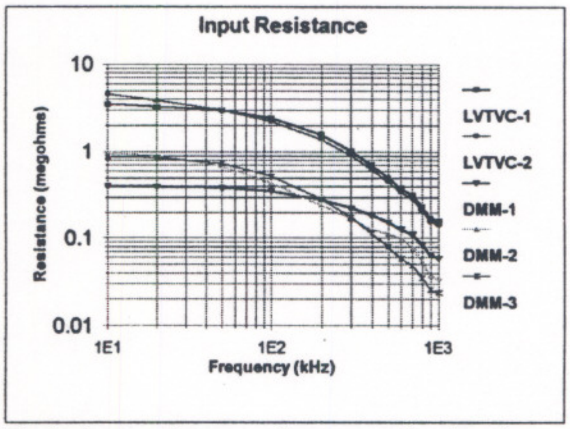

Fig.2. Input resistance vs frequency of various low voltage ac measuring instruments.

References:

1. N. Oldham and R. Henderson, "New Low-Voltage Standards in the DC to 1 MHz Frequency range," IEEE Trans. Instrum. Meas., vol. 40, no. 2, pp. 368-372, April 1991.